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(71) Applicant(s)
Motorola Limited
(Incorporated in the United Kingdom)
European Intellectual Property Operation, Jays Close, Viables Industrial Estate, BASINGSTOKE, Hampshire, RG22 4PD, United Kingdom

(72) Inventor(s)
Eric Villier
Nicholas William Anderson
Reza Karimi
Paul Anthony Howard

(74) Agent and/or Address for Service
Marc Morgan
Motorola Limited, European Intellectual Property Operation, Midpoint, Alencon Link, BASINGSTOKE, Hampshire, RG21 7PL, United Kingdom

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(54) Abstract Title
Transmitting a downlink signal in different directions at different times

(57) In a communication system having two units 10, 12 the directions of selected signals from a plurality of multipath uplink signals from unit 12 (P1, P2, P3 figure 1) are determined to be the directions p1, p2, p3 of transmission of the downlink signal from the unit 10. The downlink signal is transmitted in different directions in different time intervals thus reducing cross-cell interference and introducing diversity gain in the reception at unit 12. The communication unit 10 has an antenna (e.g. adaptive antenna, an antenna array or steerable beam) able to partition the receiving/transmitting area into a plurality of sectors S1 -SK and processing of the multipath uplink transmission from unit 12 determines principal signals P1-PM and the sectors S1-SM in which they are received. The principal signals can be for example, signals exceeding a predetermined power level or a set number (M) of the strongest signals. The downlink signals can be transmitted one sector at a time in a random or predetermined sequence and preferably the period of transmission in a sector is inversely proportional to the number of transmission signals or sectors SM. The transmission time could also be related to the transmission power, with lower power transmissions having longer duration. The transmission power for each sector may be inversely proportional to the power of the signal received in that sector.

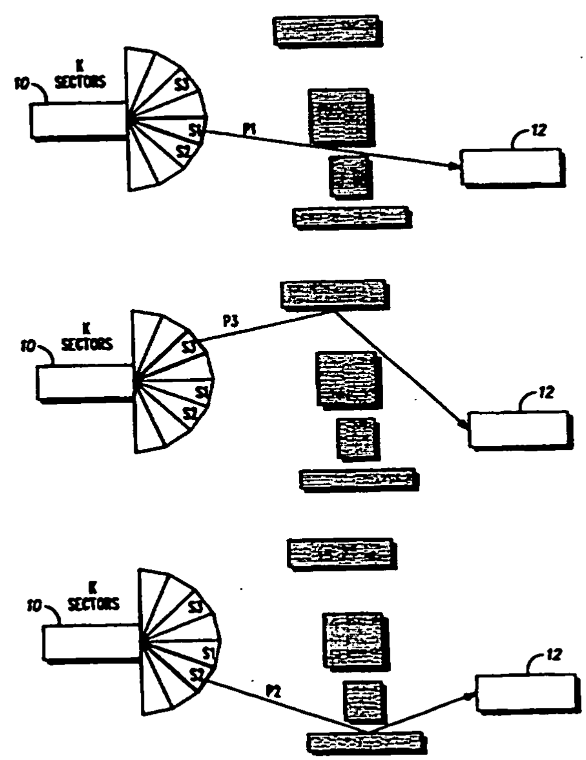

FIG.2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

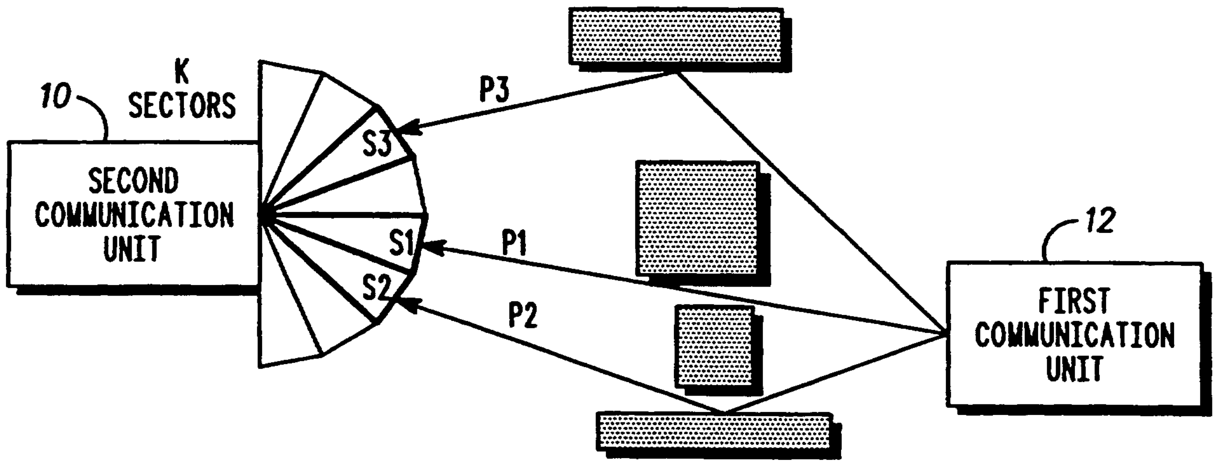
10
K SECTORS
SECOND COMMUNICATION UNIT
S3
S1
S2
P3
P1
P2
12
FIRST COMMUNICATION UNIT

FIG.1

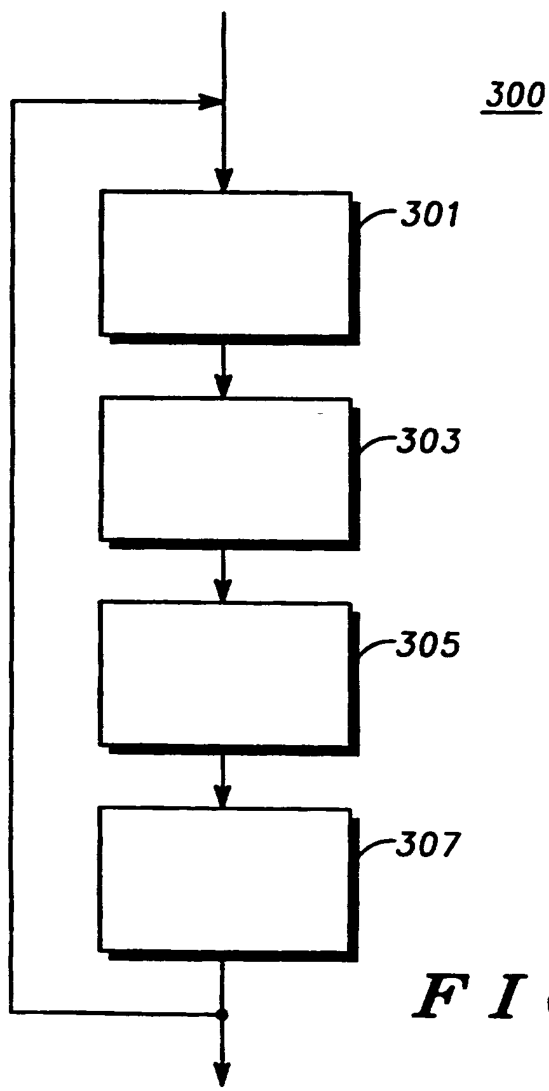
300
301
303
305
307

FIG.3

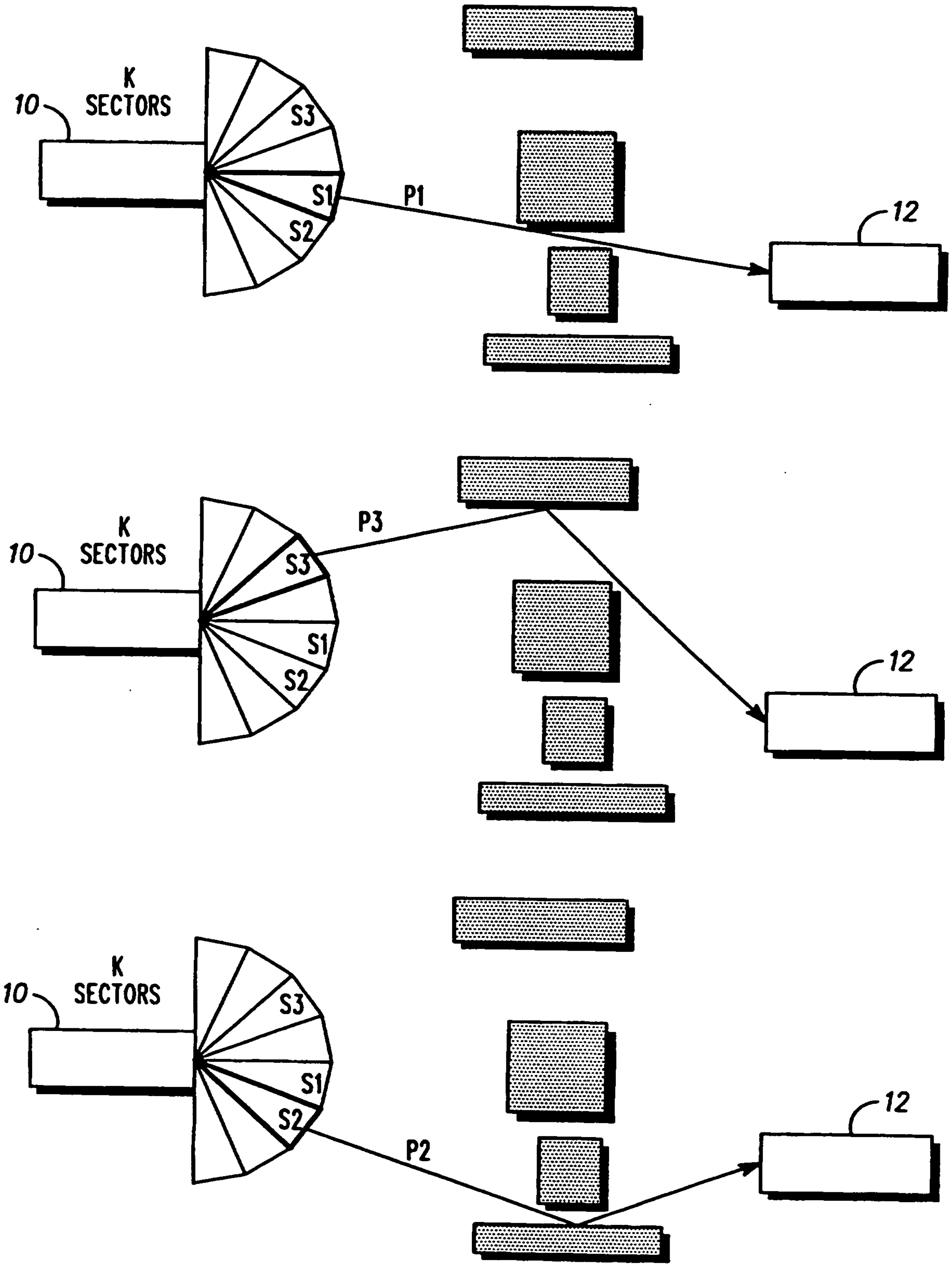
10
K
SECTORS
S3
S1
S2
P1
12
10
K
SECTORS
P3
S3
S1
S2
12
10
K
SECTORS
S3
S1
S2
P2
12

FIG.2

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METHOD OF TRANSMISSION AND RELATED APPARATUS

Field of the Invention

The present invention relates to a method and apparatus for improving communication in a radio communication system, for example a cellular communication system.

Background of the Invention

Interference is one of the key factors in determining the capacity of for example a modern cellular system. Interference may be in the form of co-channel interference due to frequency re-use patterns in cellular systems or in the form of multiple access interference in direct sequence-code division multiple access (DS-CDMA) systems.

Interference reduction systems will become of paramount importance in expected standards for third generation cellular systems which are currently being developed.

One method of reducing interference is described with reference to FIG. 1.

In one cell there is provided at a second communication unit an adaptive antenna. This antenna typically includes an array of transceivers which are operable at adjustable signal phases to steer the receiving or transmitting beam in dependence upon the received mobile signal(s). In this example, different phase adjustments are used to create a plurality of receiving sectors S1 ... Sk within the angular operating band of the antenna. Generation of these sectors enables the antenna to monitor signals from and to transmit signals within selected sectors, as is apparent in FIG. 1.

A signal from a first communication unit will typically include a plurality of primary signal components P1-Pn, formed as a result of multi-path propagation effects. The signal components P1-Pn may reach the antenna from different directions and in different sectors, as depicted in FIG. 1.

The concept involves monitoring the spatial signal environment within the plurality of sectors, in this example K sectors. The system selects as

primary components those received signal components from the first communication unit which for example exceed a predetermined power level. Alternatively, the system may select a given number of the strongest signal components or enough of the strongest signal components to reach a given percentage of the received power. The selected primary signal components are then used to determine the spatial signal environment as follows.

The primary signals are determined as arriving to M angular sectors S1 ... SM from the total of K sectors, centered around M angles q1 ... qM and having fractional power levels determined as P1/Pu > P2/Pu > ... > PM /Pu respectively (Pu being the total uplink power received).

One approach would be for the second communication unit to transmit full power along the sector S1 corresponding to the largest fractional power sector measured in the uplink communication. However, this approach may not work adequately, particularly in frequency division duplex (FDD) systems, in which uplink and downlink propagation characteristics may differ as a result of different transmission frequencies.

A more effective strategy would be for the second communication unit to transmit its signal along all the sectors S1 ... SM at similar fraction power levels as the received signal components.

A problem with the above-proposed strategies is that they can result in significant interference for the whole duration of the transmission of the second communication unit.

Summary of the Invention

The present invention seeks to provide improved communications between a first and second communication unit.

According to an aspect of the present invention, there is provided a method of transmitting signals from a second communication unit to a first communication unit in a communication system including the steps of

identifying a plurality of uplink signals received at the second communication unit from the first communication unit as a result of multi-path propagation, determining a plurality of transmission directions as the directions of receipt of the plurality of uplink signals relative to an antenna of the second communication unit, and transmitting a downlink signal from the second communication unit to the first communication unit along each transmission direction over a transmission period, wherein the transmitting step includes transmitting the downlink signal in one or more selected ones of the transmission directions for a time less than the transmission period.

This method reduces cross-cell interference which can be caused by one of the transmissions and can also provide an increase in system capacity.

Preferably, the signal is transmitted in a single direction at a time. The signal may be transmitted in all of the plurality of transmission directions in a predetermined or random sequence.

Advantageously, the time of transmission of each signal is inversely proportional to the number of transmission of signals needed to transmit in all of the plurality of directions.

According to another aspect of the present invention, there is provided a communication apparatus for communicating with a first communication unit including a second communication unit comprising an adaptive antenna, the second communication unit being operable to identify a plurality of uplink signals received from the first communication unit as a result of multi-path propagation, to determine a plurality of transmission directions as the directions of receipt of the plurality of uplink signals relative to the antenna of the second communication unit; the second communication unit including means to generate and transmit through the antenna a downlink signal along each transmission direction over a transmission period, and operable to transmit the downlink signal in one or more selected ones of the transmission directions for a time less than the transmission period.

Brief Description of the Drawings

An embodiment of the present invention is described below, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 is a schematic view of an example of communication between a first and second communication unit using spatial filtering; and

FIGs. 2a to 2c are schematic views of a preferred embodiment of communication between a first and second communication unit using spatial filtering.

FIG. 3 is an illustration of a flowchart for a method of transmission in accordance with the present invention.

Description of a Preferred Embodiment

Referring to FIGs. 2a to 2c, the second communication unit 10 is provided with an antenna array which is operated at varying phase differences to partition the antenna transmission/receiving area into K sectors S1 .. Sk, in similar manner to the example of FIG. 1.

As in FIG. 1, a signal from a first communication unit 12 communicating with the second communication unit 10 will typically be reflected off objects to produce a plurality of reflected signals. The second communication unit 10 is set up to identify from the plurality of signals received during an uplink communication those signals P1-PM, in this example P1-P3, which satisfy a predetermined criterion. The criterion can be that the signal level exceeds a predetermined power threshold level or the strongest M signals can be chosen. Using the criterion, the second communication unit 10 is operable to determine the sectors S1-SM, in this example S1-S3, in which the signals are received.

As in the example of FIG. 1, the second communication unit 10 can calculate fractional power levels for the received signals P1-P3 and classify the signals accordingly.

The preferred embodiment provides for sequential transmissions in one sector to another, as depicted in FIGs. 2a to 2c. More specifically, the second communication unit 10 transmits a signal in one sector S1-S3 at a time. The sector chosen can be switched at regular intervals, such as on a slot-by-slot basis.

FIG. 3 illustrates a flowchart of an example of a method 300 according to the invention. Step 301 consists in identifying a plurality of uplink signals received at the second communication unit from the first communication unit as a result of multi-path propagation. In step 302 the direction of arrival of these signals are determined. Techniques for identifying the signals and the direction of arrival are known in the art and need not be described.

In step 305, a signal is transmitted from the second communication unit in at least one of the identified directions during a time interval, and in step 307 this signal is transmitted in at least one different of the identified directions during a different time interval. Steps 305 and 307 can be repeated in order to transmit the signal in more than two different directions or set of directions. Steps 301 to 307 may furthermore be continually repeated in order to modify the transmission as the channel changes with time.

The described scenario is applicable to a cellular mobile communication system in which the first communication unit could be a mobile unit and the second communication unit could be a base station. In line with this, the direction of transmission from the first communication unit to the second communication unit is denoted uplink and the reverse direction is denoted downlink in the following description.

Selection of the sector in which a downlink transmission is to be effected can either be predetermined, such as in order of fractional power level, or random, or a combination of these.

In the preferred embodiment, each downlink signal is transmitted in a sector at a power level r1-r3 which is inversely proportional to the fractional power level of the relevant received signal P1-P3. This increases the chance of the downlink signal being of a sufficient power level when received by the first communication unit 12.

The duration of the downlink signal in each sector S1-S3 will only be for a proportion of the total downlink transmission time. For example the duration can be inversely proportional to the number of sectors used. Alternatively, the duration of the transmission period for each sector can be increased for sectors with lower transmitted power so that sectors which cause less instantaneous interference are used for a higher proportion of the time.

The sectorised transmission reduces the degradation caused by interference since any interference which is created lasts for only a fraction (for example 1/M) of the total transmission time. The actual interference transmitted into the system as whole by the second communication unit is likely to increase compared to transmitting the signal continuously in the best sector, as the transmitted power will be higher for the other sectors. However, as the sectors cover different geographical areas, a communication unit in one area will only be affected for a fraction of the time and the interference caused to any one communication unit is therefore likely to be reduced significantly. In addition, the interference will be concentrated in a short interval and the degradation caused by the interference will be substantially reduced when interleaving and forward error correcting coding is used. Such a reduction in the degradation caused by interference can significantly increase system capacity.

Moreover, the selection of primary signals P1-P3 from the totality of received uplink signals can reduce delay spread on downlink

communication by reducing the required number of multi-path components for transmission in the sectors S1-S3.

Another significant advantage of such sequential transmission in different sectors is that it provides channel diversity for the first communication unit 12 which especially is advantageous for slow moving units where fades can remain for long durations. The sequential transmission will result in the transmission switching between a number of paths and a fade of one of the paths will only affect the transmission for a fraction of the total transmission time. The degradation caused by the fade will be reduced significantly by interleaving and forward error correcting coding extending over several transmission periods.

It is not necessary for downlink transmissions to be limited to transmission in a single sector. There may be instances when transmission in a single sector will not be adequate, such as when transmission along a single path would provide insufficient received signal power at the first communication unit 12. Such a situation could be detected on the basis of the fractional power levels of the received uplink signals P1-PM.

In such a case, the second communication unit 10 may transmit downlink signals over more than one sector S1-SM at a time to provide adequate received signal strength. A multi-path transmission of this type could select the sectors for transmission on the basis of a predetermined criterion or randomly, as described above.

Rather than use an antenna array with predefined sectorisation, the invention can be used with continuously steerable beams as would be apparent to the person skilled in the art.

The invention thus provides a method and related apparatus for transmission of a radio signal in different directions in different time intervals, thereby reducing the interference caused by the transmission and introducing diversity gain in the reception.

Claims

1. A method of transmitting signals from a second communication unit to a first communication unit in a communication system comprising the steps of:

identifying a plurality of uplink signals received at the second communication unit from the first communication unit as a result of multi-path propagation,

determining at least a first and second direction of transmission as the directions of receipt of a first and second of the plurality of uplink signals relative to an antenna of the second communication unit;

transmitting a downlink signal from the second communication unit to the first communication unit along said first direction during a first transmission period; and

transmitting the downlink signal from the second communication unit to the first communication unit along said second direction during a second transmission period different from said first transmission period.

2. A method as claimed in claim 1, wherein said first transmission period and second transmission period do not overlap.

3. A method as claimed in claim 1, wherein the downlink signal is transmitted in a single direction at a time.

4. A method as claimed in claim 1, further comprising the step of:

identifying a third direction of transmission; and

transmitting the downlink signal along said third direction during said first transmission period.

5. A method according to claim 1, wherein said first transmission period and said second transmission period are repeated in a predetermined sequence.

6. A method according to claim 1, wherein said first transmission period and said second transmission period are repeated in a random sequence.

7. A method according to claim 1, wherein a number of transmission directions are chosen from said plurality of uplink signals and a transmission period for transmission of the downlink signal along each of the number of transmission directions is inversely proportional to the number of transmission directions chosen.

8. A method according to claim 1, wherein the downlink signal is transmitted in said first direction at a power determined in response to a power level of a received uplink signal in said first direction.

9. A method according to claim 8, wherein said power is inversely proportional to said power level.

10. A method according to claim 8, wherein said first transmission period is longer than said second transmission period if said downlink signal is transmitted at a higher power during said first transmission period than during said second transmission period.

11. A method according to claim 1, including the step of determining whether the downlink signal in said first transmission period is received with sufficient quality by the first communication unit, and if not, transmitting the downlink signal in a third direction of transmission determined as the direction of receipt of a third of the plurality of uplink signals.

12. A communication apparatus for communicating between a first communication unit and a second communication unit comprising:

means for identifying a plurality of uplink signals received at the second communication unit from the first communication unit as a result of multi-path propagation,

means for determining at least a first and second direction of transmission as the directions of receipt of a first and second of the plurality of uplink signals relative to an antenna of the second communication unit;

means for transmitting a downlink signal from the second communication unit to the first communication unit along said first direction during a first transmission period; and

means for transmitting the downlink signal from the second communication unit to the first communication unit along said second direction during a second transmission period different from said first transmission period.

13. A communication apparatus as claimed in claim 12, wherein said first transmission period and second transmission period do not overlap.

14. A communication apparatus as claimed in claim 12, further comprising:

means for identifying a third direction of transmission; and

means for transmitting the downlink signal along said third direction during said first transmission period.

15. A communication apparatus as claimed in claim 12, wherein said first transmission period and said second transmission period are repeated in a predetermined sequence.

16. A communication apparatus as claimed in claim 12, wherein said first transmission period and said second transmission period are repeated in a random sequence.

17. A communication apparatus as claimed in claim 12, wherein the downlink signal is transmitted in said first direction at a power determined in response to a power level of a received uplink signal in said first direction.

18. A method of transmitting signals from a second communication unit to a first communication unit in a communication system substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

19. A communication apparatus for communicating with a first communication unit substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

The Patent Office

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Application No: GB 9725743.0
Claims searched: 1-17

Examiner: Anita Keogh
Date of search: 17 April 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4L (LDDRX, LDDSX)

Int Cl (Ed.6): H04B (7/02, 7/10), H04L (1/02)

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A, E	WO 97/02666 A1	(NOKIA) see whole document	
A	WO 96/37975 A1	(NOKIA) see whole document	
X	WO 96/37973 A1	(NOKIA) see pages 1-17, particularly page 10 line 25 to page 11, line 30, page 13, lines 3-12, page 15 lines 3 - 34 and page 17, lines 21-30	1, 12 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.